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(56) Documents cited
US 4501151 A
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(54) **Ultrasound therapy apparatus**

(57) The apparatus comprises a treatment head 10 to which an alternating electrical signal is applied to generate a beam of ultrasound of frequency dependent upon that of the alternating signal and signal generating means which is operative to frequency modulate the alternating signal. The alternating signal may be generated by oscillator circuits in a control unit which are controlled by a software program executed by a microprocessor and may be modulated cyclically or randomly about the natural frequency, or one of the harmonic frequencies, of the piezo-electric crystal which creates the beam. The beam non-uniformity ratio (BNR) may thereby be reduced from a value of, for example, 4 or more in a conventional ultrasound therapy apparatus to an effective value close to unity.

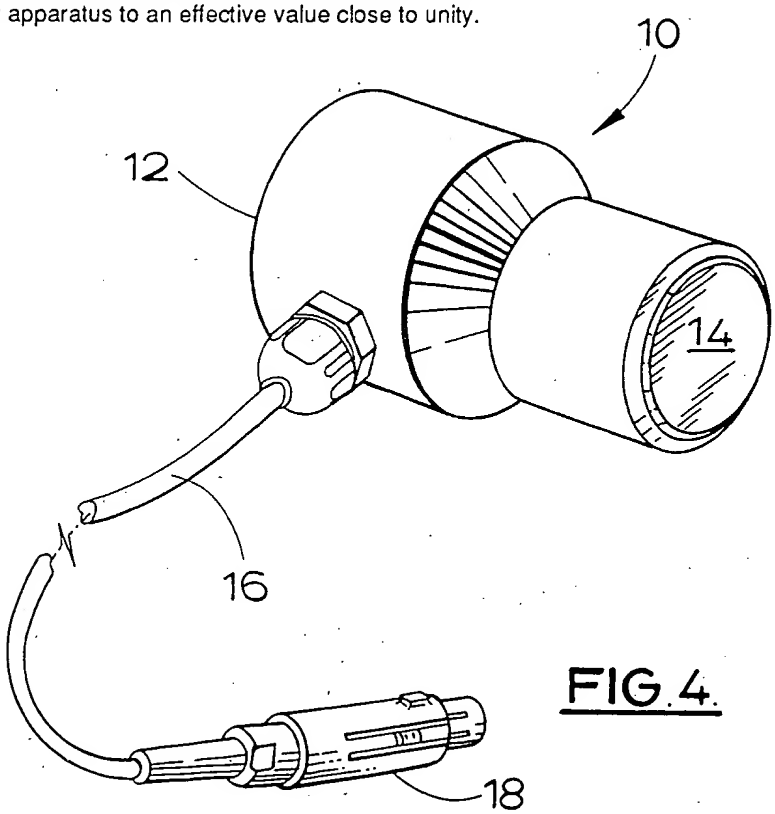

FIG.4.

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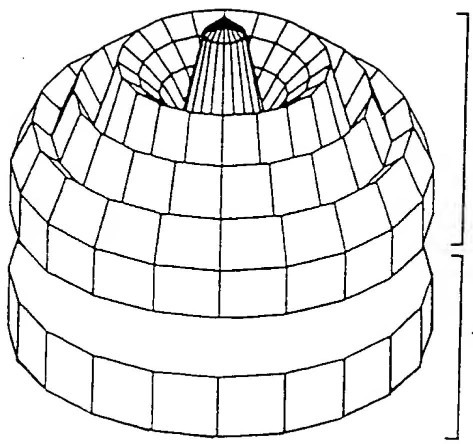

PRIOR ART.

FIG.1.

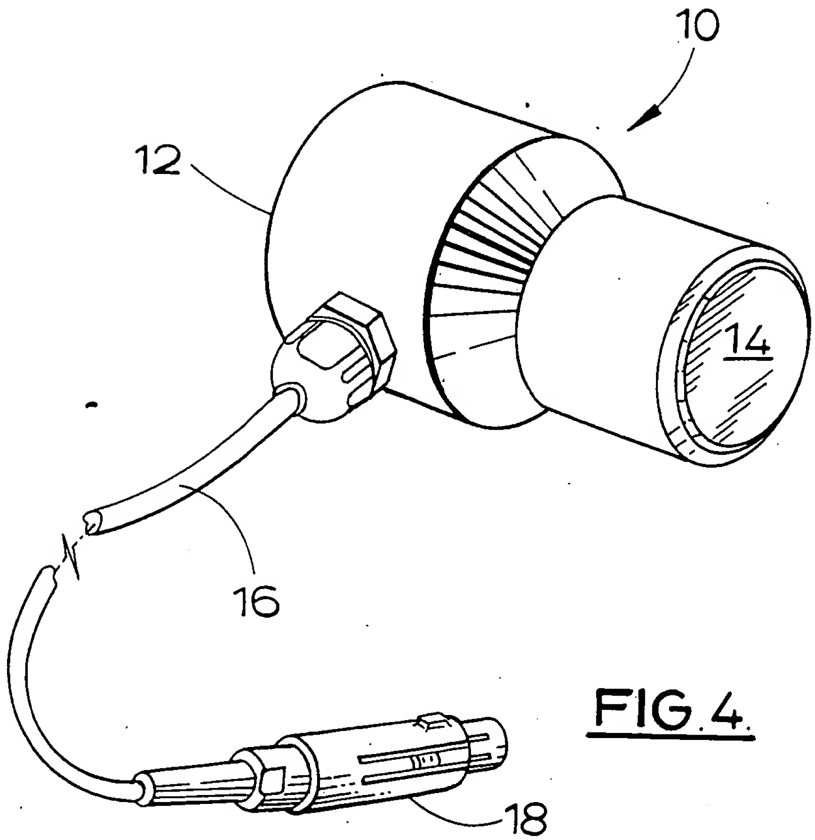

FIG.4.

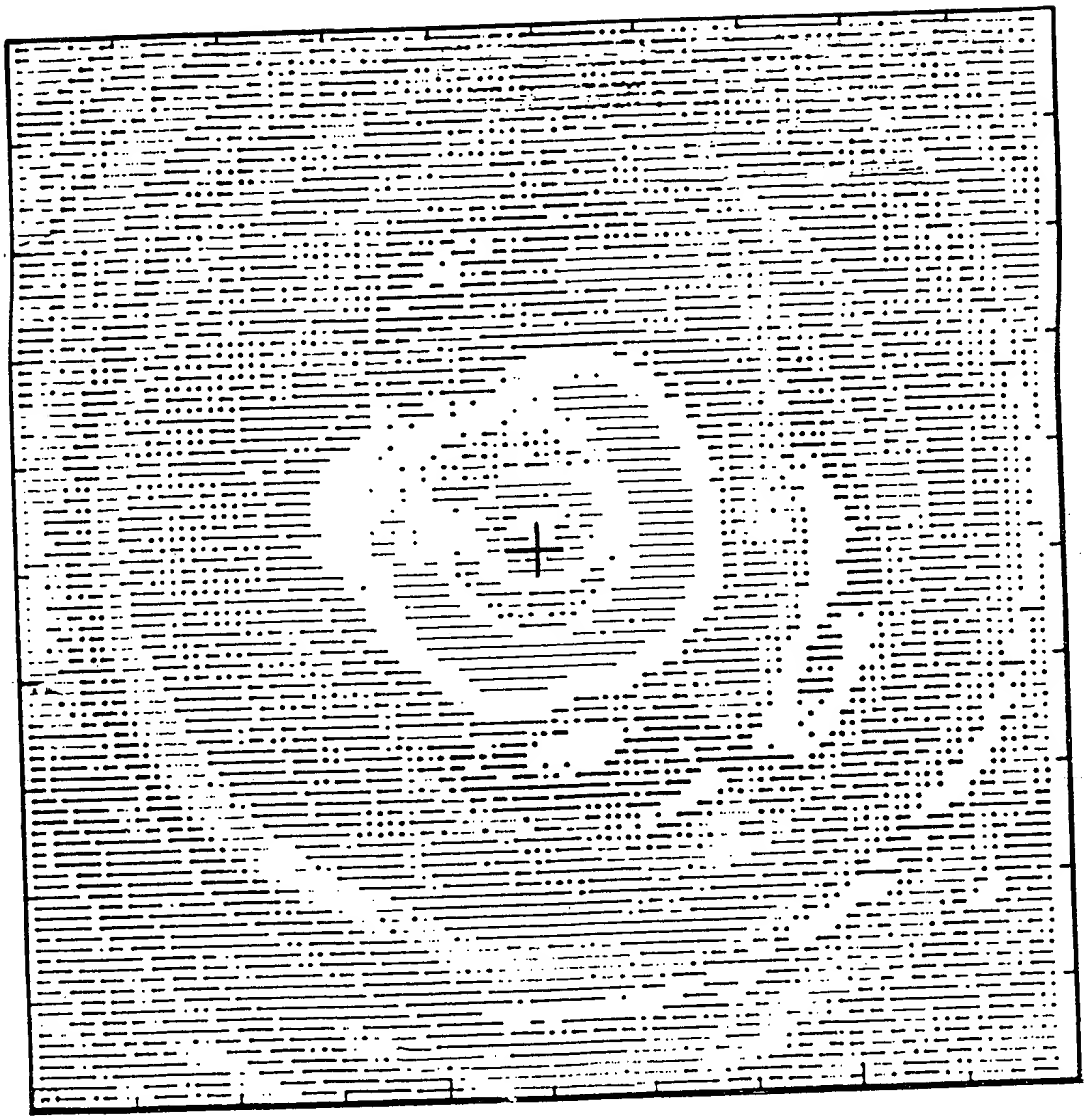

FIG. 2.

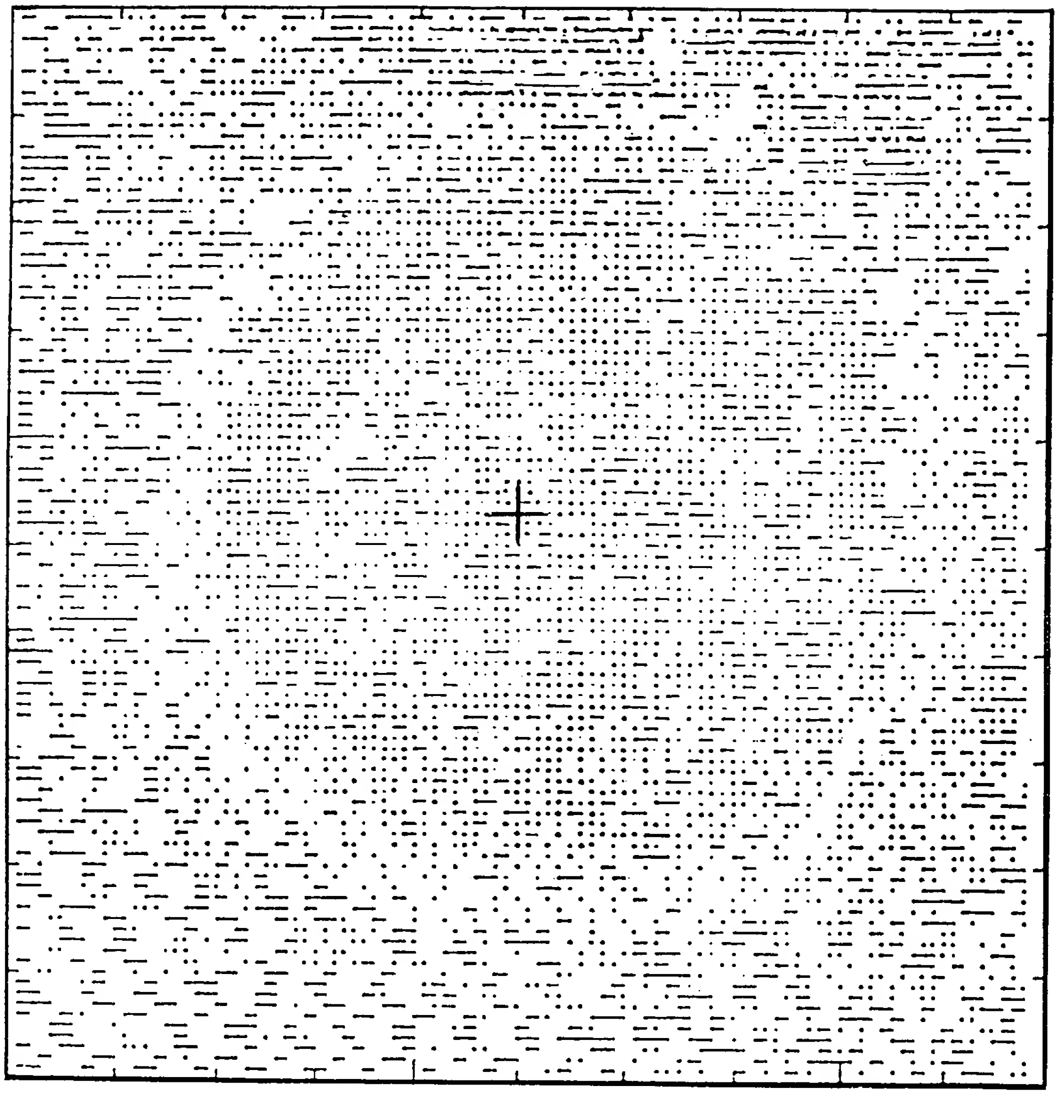

FIG. 3.

ULTRASOUND THERAPY APPARATUS

The present invention relates to ultrasound therapy apparatus.

Ultrasound therapy is used in physiotherapy to reduce pain, to stimulate tissue repair, and to treat a variety of clinical conditions including strained and torn ligaments, inflamed tendons and tendon sheaths, and lacerations and other soft tissue injuries.

Ultrasound therapy is carried out by application of a treatment head to the affected area. The treatment head typically contains a piezo-electric crystal, electrically connected to a control unit which generates an alternating electrical signal to drive the crystal into mechanical oscillation. The crystal is, in such arrangements, mechanically connected to a treatment face of the treatment head which is thus caused to vibrate, so creating a beam of ultrasound which radiates from the face and, in use, into the affected tissue.

Conventional ultrasound therapy apparatus produces an ultrasound beam which is substantially rotationally symmetrical about an axis which extends longitudinally of the beam but which has an amplitude which varies with the radial distance from the axis. Figure 1 shows the profile of a typical ultrasound beam, with a central peak and several concentric peaks and troughs around the central peak. (In Figure 1, region A represents the beam and region B represents a treatment face.) The ratio of the highest peak amplitude of the beam to the average amplitude of the beam is called "the beam non-uniformity ratio" (BNR). Typical known ultrasound therapy apparatus has a BNR of 4 or more.

The disadvantage of the non-uniform beam is that if the treatment head is not kept moving while in contact with the treatment area, there will be local variations in the amount of ultrasound treatment received. This can cause local overexposure with the possible result that tissue damage will occur. Rotation of the treatment head will not alleviate this effect since the beam is rotationally symmetrical.

It has been found that the main causes of beam non-uniformity are in typical treatment heads (a) the formation of standing waves on the piezo-electric crystal surface and (b) interference within the beam of waves emanating from different parts of the crystal surface, and, having travelled along paths of different lengths, arriving at a point within the beam and there adding or cancelling with one another, so raising or lowering the beam amplitude at that point.

The present invention provides in a first of its aspects ultrasound therapy apparatus comprising a treatment head, operative on application of an alternating electrical signal thereto to generate a beam of ultrasound at a frequency related to that of the alternating signal, and signal generating means to apply an alternating signal to the treatment head, the signal generating means being operative to frequency modulate the alternating signal.

Investigation has shown that a change in the frequency of the driving signal does not necessarily reduce the instantaneous BNR but causes the position of the peaks to change. Furthermore, a small frequency change can cause a relatively large change in the position of the peaks.

The result of frequency modulation is that the positions of the peaks constantly change so, averaged over time, the amplitude of the beam at any point within the effective area of the beam tends to be of a value nearer to the amplitude averaged over the area of the beam. Thus, the BNR is effectively reduced.

Preferably, modulation takes place at a rate which is rapid as compared with the total time for which the beam will be applied to tissue during a treatment session. This ensures that, during a treatment session, the beam is generated at all frequencies within its range of modulation, so allowing maximum effect to be achieved from the modulation.

Preferably, frequency modulation of the signal takes place cyclicly, randomly or otherwise around a predetermined reference frequency. This reference frequency may, in some embodiments, be selectable by a user.

Typically, the invention will be embodied in an ultrasound therapy apparatus having a piezo-electric crystal as described in the third paragraph of page 1 of the specification. In such an embodiment, it is undesirable to drive the crystal with a signal of frequency significantly different from the natural frequency of the crystal, or one of its harmonics as this would result in loss of output amplitude and cause heating of the crystal. It has been found that frequency modulation of 1% is sufficient to disrupt the peaks and troughs of the beam without excessive degradation of the output.

In many known ultrasound therapy apparatus, the driving signal frequency is controlled by a software

program executed by a microprocessor. In such apparatus, the invention may be put into practice by re-programming the software to vary the frequency cyclicly or randomly by a small amount during operation of the unit.

In a second of its aspects the invention provides a method of operating an ultrasound therapy apparatus said apparatus comprising a treatment head operable to generate a beam of ultrasound at a frequency dependent upon the frequency of an alternating electrical signal applied thereto, comprising applying to the treatment head an alternating electrical signal of a predetermined reference frequency and modulating the frequency of the signal about the reference frequency.

An embodiment of the invention will now be described in detail, by way of example, with reference to the accompanying drawings, in which:-

Figure 1 is a diagram of the beam profile of a known ultrasound therapy apparatus, and has already been referred to;

Figures 2 and 3 show the results of measurement of an ultrasonic beam respectively of a conventional treatment apparatus and of a treatment apparatus embodying the invention; and

Figure 4 shows a treatment head suitable for use with apparatus embodying the invention.

An ultrasonic treatment apparatus comprises a control unit (not shown) and a treatment head 10. The treatment head, which is conventional in design, has a body 12 in which is contained a piezo-electric

crystal. At one end of the body 12 there is a treatment face 14 in the form of a flat-surfaced metal plate which is mechanically linked to the crystal. An electric lead 16 connects the treatment head to the control unit, through a connector 18. In operation the control unit generates an oscillating electric driving signal which is fed through the lead to the crystal, so causing it to oscillate. These oscillations are conducted to the treatment face 14, causing it to vibrate, the vibrations generating a beam of ultrasound which radiates from the plate.

In a typical ultrasound apparatus, the natural frequency of the crystal is chosen to be nominally 1 MHz. However, it will be appreciated that every crystal will have a slightly different natural frequency due, for example, to manufacturing tolerances and defects in the crystal lattice. For the apparatus to perform efficiently, it is important that the frequency of the driving signal is very close to the natural frequency of the crystal, or to one of its harmonics. If the exciting frequency varies significantly from the natural or harmonic frequency, less energy from the driving signal will be converted to ultrasound and the crystal will become hot. The degree of frequency modulation is kept low to prevent appreciable side-band energy from falling outside the pass-band of the natural frequency of the crystal, so as to maintain driving efficiency while frequency modulation is applied.

To ensure that the driving signal generated by the control unit closely matches the frequency required by the crystal, the natural frequency of each crystal is measured prior to its incorporation into the treatment

head, and frequency information is then encoded into a circuit contained within the connector 18.

The operation of the control unit is controlled by a microprocessor executing a control program. On connection of the connector 18 to the control unit, the control program causes the control unit to extract the frequency information from the circuits within the connector 18, and this value is stored in memory by the microprocessor. This stored value is then used by the microprocessor to adjust the oscillator circuits within the control unit which generate the output signals to match the frequency of the output signals to the natural frequency of the crystal.

In this embodiment, the program which controls the microprocessor contains instructions which cyclicly vary the output frequency of the oscillator circuits during output of the driving signals. The driving signal frequency is frequency modulated by a small amount, say, 1% at a centre frequency of 1 MHz, nominal.

The frequency of the driving signal can be selected by the operator to be nominally 1 MHz or 3 MHz, corresponding to driving the crystal into oscillation at its natural frequency or at its second harmonic. In both cases, the control program matches the output frequency to the exact frequency demanded by the crystal's properties and modulates the output signal, as described above.

The effect of the modulation can be seen in Figures 2 and 3. Figure 2 shows the pattern of an ultrasonic beam emitted from a treatment head fed with an un-modulated driving signal. The concentric bands of varying beam intensity are clearly evident.

Figure 3 shows the output from the same treatment head with the driving signal modulated by 1%. As can be seen, there is no pattern of non-uniformity within the beam indicating a uniform beam intensity and a BNR value closely approaching 1.

CLAIMS

1. Ultrasound therapy apparatus comprising a treatment head, operative on application of an alternating electrical signal thereto to generate a beam of ultrasound at a frequency related to that of the alternating signal, and signal generating means to apply an alternating signal to the treatment head, the signal generating means being operative to frequency modulate the alternating signal.

2. Ultrasound therapy apparatus according to claim 1 in which the alternating signal is modulated about a predetermined reference frequency.

3. Ultrasound therapy apparatus according to claim 2 in which the magnitude of the frequency modulation is substantially 1% of the predetermined reference frequency.

4. Ultrasound therapy apparatus according to claim 2 or claim 3 in which the frequency modulation is cyclic about the reference frequency.

5. Ultrasound therapy apparatus according to claim 2 or claim 3 in which the frequency modulation is random about the reference frequency.

6. Ultrasound therapy apparatus according to any preceding claim in which the alternating electrical signal is generated by oscillator circuits within a control unit, the circuits being controlled by a microprocessor executing a software control program.

7. Ultrasound therapy apparatus according to claim 6

in which the frequency modulation of the alternating signal is controlled by the software program.

8. Ultrasound therapy apparatus according to any preceding claim in which the effective BNR of the beam of ultrasound is substantially unity.

9. Ultrasound therapy apparatus according to any preceding claim in which the treatment head comprises a piezo-electric crystal to which the alternating signal is applied so as to induce vibrations therein.

10. Ultrasound therapy apparatus according to claim 9 in which the treatment head further comprises a treatment face mechanically linked to the crystal.

11. Ultrasound therapy apparatus according to claim 9 or claim 10 in which the alternating signal is modulated about a predetermined reference frequency, said reference frequency being substantially equal to the natural frequency of the crystal or a harmonic thereof.

12. A method of operating an ultrasound therapy apparatus said apparatus comprising a treatment head operable to generate a beam of ultrasound at a frequency dependent upon the frequency of an alternating electrical signal applied thereto, comprising applying to the treatment head an alternating electrical signal of a predetermined reference frequency and modulating the frequency of the signal about the reference frequency.

13. A method of operating an ultrasound therapy apparatus according to claim 12 in which the magnitude

of the frequency modulation is substantially 1% of the predetermined reference frequency.

14. A method of operating an ultrasound therapy apparatus according to claim 11 or claim 12 in which the frequency modulation is cyclic about the reference frequency.

15. A method of operating an ultrasound therapy apparatus according to claim 11 or claim 12 in which the frequency modulation is random about the reference frequency.

16. A method of operating an ultrasound apparatus according to any one of claims 11 to 16, the treatment head comprising a piezo-electric crystal operative to generate mechanical vibrations on application of an alternating electrical signal thereto, in which the reference frequency is substantially equal to the natural frequency of the crystal or a harmonic thereof.

17. Ultrasound therapy apparatus substantially as hereinbefore described with reference to the accompanying drawings.

18. A method of operating an ultrasound therapy apparatus substantially as hereinbefore described with reference to the accompanying drawings.

Examiner's report to the Comptroller under Section 17 (The Search Report)

GB 9300839.9

Relevant Technical fields

(i) UK Cl (Edition L) A5R (REK)

(ii) Int Cl (Edition 5) A61B, A61F, A61H

Search Examiner

L V THOMAS

Databases (see over)

(i) UK Patent Office

(ii) ONLINE DATABASE: WPI

Date of Search

20 APRIL 1993

Documents considered relevant following a search in respect of claims 1-18

Category (see over)	Identity of document and relevant passages	Relevant to claim(s)
X	US 4501151 (CHRISTMAN) see lines 39-51 column 8	1,2,5,12, 15
X	WPI Abstract Acc. No. 87-248860/35 and SU 001284521 A (KIER ORTHOLARYNGOLS) - see abstract	1